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Author Productivity of COVID-19 Research Output Globally: Testing Lotka's Law

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Abstract

COVID-19 is a novel virus with lethal effects on human health, causing respiratory failure and infiltration in the lungs. The present study attempted to examine global publication trends in research associated with COVID-19 and sought the fitness of Lotka's Law, data downloaded from the WHO database (https://www.who.int/). The search term "2019nCoV, COVID -19" was used to retrieve articles published from December 2019 to March 19, 2020. Two thousand two hundred eighteen authors have contributed a total of 2250 articles. Four clusters formed on "author title/abstract," the terms hospital, CoV, coronavirus, pneumonia found associated with 20674 terms, out of which 797 met the threshold. Co-authorship pattern of COVID-19 research generated 6 clusters with 65 authors, "Nishiura, Hiroshi" surpassed the list of co-authors followed by He, Daihai, Zhao, Shi and Zhang, Wei. The Lotka's Law on Authors' Productivity on COVID-19 Literature confirmed the applicability of the Law to the present data collection. The goodness of fit-Kolmogorov-Smirnov (KS) measured in the COVID-19 research to quantify the pragmatism of the Lotka's rule between the observed collection of data counter to the inverse square rule relation and the possible value of n=2.

Keywords: Author Productivity, Research Output, COVID-19, Corona Virus, Lotka's Law

Introduction

Since the time Lotka's article was published in 1926, a great deal of research made on the author's productivity in various disciplines. Research contributions found linked to Lotka's work referred to supporting his discoveries (Egge 2005). Consequently, many types of scientific research point out that there are valid indicators for measuring the degree of scientific output of a particular discipline, organization, author, research program and nation (Garfield 1979; Furner 2014; Vinkler, 2010).

Various bibliometric studies reported on deadly infections and pathogens viz. Hepatitis (Ramakrishnan and Ramesh 2007); Oncolytic infection (Zao et al. 2019); Pleisiomonas (Ekundayo and Okho 2018); Zika virus (Frances 2018); Dengue (Zyoud 2016); Ebola virus (Garg and Kumar 2017). Further productivity patterns of authors using publications on acute infections are done extensively and tested for Lotka's Law. In the current study, Lotka's Law tested for the author's productivity onCOVID-19 research to confirm the pertinence of the Law to the current dataset. K-S test applied against the inverse square law and the stochastic estimation of n = 2 to quantify the level of understanding between the circulation of the obtained set of information.

The emergence of COVID-19 outbreak

Unexplained low respiratory infection identified in Wuhan, the largest metropolitan area in China's Hubei province, and was first notified to the WHO(World Health Organisation) Country Office in China on December 31, 2019, in the course of events that arrives at the present day. Such first cases called "pneumonia of unknown etiology" since they could not classify the causative pathogen. The Chinese Center for Disease Control and Prevention (CDC) and adjacent CDCs were undertaking an intensified outbreak sequence. This disease's etiology is generally due to a new infection with the coronavirus (CoV) gene. (Li et al. 2020). The new coronavirus liable for the 2019-2020 pandemic causes a sickness termed COVID-19. The virus gains entry through one's eyes, nose, or mouth. It, at that point, takes hold of the cells by connecting its spikey surface proteins to receptors on healthy cells, particularly those in the lungs. In particular, the viral proteins bust into cells through the ACE2 (angiotensin-changing over a catalyst

2) receptors, they further attack the immune system and respiratory tract leading to the death of the individual (Huang et al. 2020).

Review of Literature

Maz-Machado et al. (2017) considered Information Science & Library Science journals during the years 1956 and 2014 to find fitness of the Lotkas Law. Factors such as C and α extracted using the least - square linear method, and further K-S test was applied. Findings showed that the trend of under-study LIS publication suited Lotka's Law. Subsequently, Beverly et al. (2013) examined journals in clinical radiation sciences for eight years (2004–2011). Besides, the most significant author gave an evaluation of their individualities. At the 0.01 level of significance, the dataset failed to fit the Lotka's law since n = - 2.334; c = 0.712; Dmax = 0.0627; and C = 0.0337.

In another study, Danesh and Ghavidel (2020) intended to study the Coronavirus scientific publications for five decades in the world. The statistics of the article included 5128 articles indexed on the Web of Science from 1970 to 2019. Results revealed that maximum publications were during the period 2005, and the year 2019 received the sheer number of citations. The results showed, there remained a straight relationship between the Coronavirus outbreaks and the number of Scientific Publications globally. Chiu et al. (2004) performed an early stage bibliometric study of the related scientific publications on Severe Acute Respiratory Syndrome (SARS), available in the Science Citation Index (SCI). The investigation considered authorship patterns, international collaboration, journals, language, document type, research institution, and citation number.

Objectives

This article intends to identify author productivity in the COVID-19 research yield with the objectives as following:

- Verify the applicability of the Lotka's inverse square law.
- Apply Kolmogorov Smirnov (K-S) goodness of fit test to confirm the Lotka's Law.
- Identify a Co-authorship pattern on COVID-19 research.
- Recognize the most common terms in the authors' title/ abstract.

Methodology

On 20/03/2020, from the WHO website (https:/www.who.int/crises/sicknesses/novel-coronavirus-2019/worldwide), the data for this analysis retrived, for three months and 20 days (December 1, 2019, to March 19, 2020). The quests performed on the name of COVID-19, 2019 nCoV, SARS COV-2 utilizing the first hunt at the PubMed Core Collection, with all probabilities and bibliographic details of 2168 research articles contributed by 2146 authors published in 1964 journals gathered for this investigation. The aim of this thesis in COVID-19 research is to check Lotka 's science productivity law using the methodology outlined by Pao (1985). Further, the records were analyzed by utilizing VOS and Bibexcel, SPSS programming applications. The authors acknowledged for each article in which their name was present and analyzed to confirm the fitness of the Lotka's Law at 0.01 level of significance.

Lotka's Inverse Square Law determining the value of 'n,' 'c' and 'C V.'

A classic article contributed by Alfred J. Lotka (1926) on his study of the scientific productivity of the author, analyzed the articles related to Chemical Abstracts during the years 1907-16. The Law states, "the number of authors making 'n' contributions is approximately $1/n^2$ of those contributing one, and the possibility of authors making a single publication is essentially 60%". Meaning 60% of the authors make one contribution in a subject or discipline; 15% yield two outputs (1/22 * 60); 7 % give out three distributions ($1/3^2$ * 60), and so on. The Law is a

systematic approach to map the authorship productivity rather than a fixed law, which differs for every discipline . Still, it provides a broader prospect of understanding the authors' productivity trend in a discipline. This paper attempted to study the pertinence of Lotka's Law to the publications of author productivity in COVID-19 related literature. The value of 'n', 'C', and 'Critical value' of the data set determined to test the suitability with the help calculations made in table 1 shown below.

Table 1: Lotka's Law (n-value) of Author Productivity in COVID-19 Research Output

S.No	No of Articles (*x*)	No of Authors Observed (*y*)	Percentage of Authors	Total no of Contributions	X Log (*x*)	Y Log (*y*)	X^2	$X*Y$	x^n	$1/x^n$
1	1	569	26.51	569	0.00000	6.343880434	0.00000	0	1	1
2	2	275	12.81	550	0.69315	5.616771098	0.48045	3.893249	3.844858	0.260088
3	3	235	10.95	705	1.09861	5.459585514	1.20695	5.997968	8.453049	0.118301
4	4	192	8.95	768	1.38629	5.257495372	1.92181	7.288436	14.78293	0.067646
5	5	160	7.46	800	1.60944	5.075173815	2.59029	8.168177	22.80605	0.043848
6	6	127	5.92	762	1.79176	4.844187086	3.21040	8.679618	32.50077	0.030768
7	7	117	5.45	819	1.94591	4.762173935	3.78657	9.266763	43.8497	0.022805
8	8	101	4.71	808	2.07944	4.615120517	4.32408	9.596873	56.83829	0.017594
9	9	57	2.66	513	2.19722	4.043051268	4.82780	8.883492	71.45403	0.013995
10	10	49	2.28	490	2.30259	3.891820298	5.30190	8.961247	87.68602	0.011404
11	11	47	2.19	517	2.39790	3.850147602	5.74990	9.232251	105.5245	0.009476
12	12	40	1.86	480	2.48491	3.688879454	6.17476	9.166521	124.9609	0.008003
13	13	24	1.12	312	2.56495	3.17805383	6.57897	8.151547	145.9871	0.00685
14	16	20	0.93	320	2.77259	2.995732274	7.68725	8.305934	218.5351	0.004576
15	14	19	0.89	266	2.63906	2.944438979	6.96462	7.770543	168.5959	0.005931
16	15	19	0.89	285	2.70805	2.944438979	7.33354	7.973689	192.7806	0.005187
17	18	17	0.79	306	2.89037	2.833213344	8.35425	8.18904	274.7306	0.00364
18	17	11	0.51	187	2.83321	2.397895273	8.02710	6.793749	245.8536	0.004067
19	19	9	0.42	171	2.94444	2.197224577	8.66972	6.469594	305.1611	0.003277
20	20	6	0.28	120	2.99573	1.791759469	8.97441	5.367632	337.1403	0.002966
21	24	6	0.28	144	3.17805	1.791759469	10.10003	5.694308	480.4568	0.002081
22	28	5	0.23	140	3.33220	1.609437912	11.10359	5.362976	648.2273	0.001543
23	25	4	0.19	100	3.21888	1.386294361	10.36116	4.462309	520.1159	0.001923

24	31	4	0.19	124	3.43399	1.386294361	11.79227	4.760517	789.9724	0.001266
25	35	4	0.19	140	3.55535	1.386294361	12.64050	4.928759	1000.038	0.001
26	22	3	0.14	66	3.09104	1.098612289	9.55454	3.395857	405.7269	0.002465
27	27	3	0.14	81	3.29584	1.098612289	10.86254	3.620847	604.0044	0.001656
28	21	2	0.09	42	3.04452	0.693147181	9.26912	2.110302	370.6637	0.002698
29	23	2	0.09	46	3.13549	0.693147181	9.83132	2.173359	442.3259	0.002261
30	26	2	0.09	52	3.25810	0.693147181	10.61519	2.25834	561.2996	0.001782
31	29	2	0.09	58	3.36730	0.693147181	11.33868	2.334032	693.9649	0.001441
32	34	2	0.09	68	3.52636	0.693147181	12.43522	2.444287	945.2723	0.001058
33	37	2	0.09	74	3.61092	0.693147181	13.03873	2.502898	1114.055	0.000898
34	45	2	0.09	90	3.80666	0.693147181	14.49068	2.638577	1629.584	0.000614
35	32	1	0.05	32	3.46574	0	12.01133	0	840.2366	0.00119
36	38	1	0.05	38	3.63759	0	13.23203	0	1173.301	0.000852
37	43	1	0.05	43	3.76120	0	14.14663	0	1491.817	0.00067
38	49	1	0.05	49	3.89182	0	15.14627	0	1922.796	0.00052
39	50	1	0.05	50	3.91202	0	15.30392	0	1999.772	0.0005
40	51	1	0.05	51	3.93183	0	15.45925	0	2078.213	0.000481
41	52	1	0.05	52	3.95124	0	15.61233	0	2158.117	0.000463
42	65	1	0.05	65	4.17439	0	17.42551	0	3329.388	0.0003
43	68	1	0.05	68	4.21951	0	17.80425	0	7.780000	0.00000
		2146	**100.00**	**11421**	**124.1356**	**93.3403**	**395.7398**	**196.8437**	**7.7800**	**1.6680**

Lotka's Law articulated in the resulting equation as $x^n * y = c$ Where 'x'

refers to the number of articles published (1, 2, 3, 4….);

'y' refers to the number of authors with frequency 'x' number of articles;

'n' is an exponent that is constant for a given set of data; and

'c' is constant.

When n=2 used for a data set, then it is termed "Inverse-square law", in this case, the value of constant 'c' =0.6079. The value of 'n' differs from the data set (Pao 1985).

$$n = \frac{N \sum XY - \sum X \sum Y}{N \sum X^2 - (\sum X)^2}$$

$$n = \frac{43 \text{ X } 196.8437 - 124.1356 \text{ X } 93.3403}{43 \text{ X } 395.7398 - (124.1356)^2} = \mathbf{1.94293}$$

n = **1.94**

$$c = \frac{1}{\sum \frac{1}{X^n}}$$

$$c = \frac{1}{1.6680} = \mathbf{0.599490415}$$

c = 0.59

$$\mathbf{c} = \frac{1}{\sum_1^{p-1} \frac{1}{x^n} + \frac{1}{(n-1)(p^{n-1})} + \frac{1}{2p^n} + \frac{n}{24(p-1)^{n+1}}}$$

$$\mathbf{c} = \frac{1}{1.640422371 + 0.003155003 + 0.001483062 + 0.000013925} = \mathbf{0.607875257}$$

c =0.61

$$\textbf{Critical Value (C V)} = \frac{1.63}{\sqrt{\sum y_x} + \sqrt{\frac{\sum y_x}{10}}}$$

$$\mathbf{C\ V} = \frac{1.63}{\sqrt{2146} + \sqrt{\frac{2146}{10}}} = \mathbf{0.026732631}$$

C V=0.026732631

Kolmogorov-Smirnov (K-S) goodness of fit test

Pao (1986) recommended non-parametric Kolmogorov- Smirnov (K-S) goodness-of-fit test to calculate the maximum deviation, D. Dmax = (Fo-Fe), for examining the observed frequency pattern of the productivity of the author conformed to the predicted frequency pattern.

Where **Fe =** expected author's cumulative frequency function.

Fo = observed author's cumulative frequency function of a sample of n observations.

At a 0.01 level of significance, the K-S statistic is equivalent to to$1.63/\sqrt{\sum y}$. As shown in table 2, D from the author productivity pattern COVID- 19 related research is **0.01415387**, and the K-S value is **0.026732631**. The value of D is lesser than the CV value, and therefore K-S test supports the applicability of Lotkas law.

Table 2: Kolmogorov-Smirnov Test

S.No	Publication (x)	Author (Yx)	Observed Author		Expected Authors		Deviation (Fo-Fe)
			Relative ($y/\sum y$)	Cumulative (Fo)	Relative $C^*(1/x^n)$	Cumulative % (Fe)	
1	1	569	0.265144455	0.265144455	0.607875257	0.607875257	-0.3427308
2	2	275	0.128145387	0.393289842	0.158100828	0.765976085	-0.37268624
3	3	235	0.109506058	0.502795899	0.071911954	0.837888038	-0.33509214
4	4	192	0.089468779	0.592264678	0.041120068	0.879008106	-0.28674343
5	5	160	0.074557316	0.666821994	0.026654124	0.90566223	-0.23884024
6	6	127	0.05917987	0.726001864	0.018703409	0.924365638	-0.19836377
7	7	117	0.054520037	0.780521901	0.0138627	0.938228338	-0.15770644
8	8	101	0.047064306	0.827586207	0.01069482	0.948923158	-0.12133695
9	9	57	0.026561044	0.854147251	0.008507221	0.957430379	-0.10328313
10	10	49	0.022833178	0.876980429	0.006932408	0.964362787	-0.08738236
11	11	47	0.021901212	0.89888164	0.005760511	0.970123298	-0.07124166
12	12	40	0.018639329	0.917520969	0.004864525	0.974987823	-0.05746685
13	13	24	0.011183597	0.928704567	0.004163898	0.979151721	-0.05044715
14	16	20	0.009319664	0.938024231	0.00278159	0.981933311	-0.04390908
15	14	19	0.008853681	0.946877912	0.003605517	0.985538828	-0.03866092
16	15	19	0.008853681	0.955731594	0.003153196	0.988692024	-0.03296043
17	18	17	0.007921715	0.963653308	0.002212623	0.990904647	-0.02725134
18	17	11	0.005125815	0.968779124	0.002472509	0.993377156	-0.02459803
19	19	9	0.004193849	0.972972973	0.001991981	0.995369137	-0.02239616
20	20	6	0.002795899	0.975768872	0.001803033	0.99717217	-0.0214033
21	24	6	0.002795899	0.978564772	0.001265203	0.998437373	-0.0198726
22	28	5	0.002329916	0.980894688	0.00093775	0.999375123	-0.01848044
23	25	4	0.001863933	0.982758621	0.00116873	1.000543854	-0.01778523
24	31	4	0.001863933	0.984622554	0.000769489	1.001313343	-0.01669079

25	35	4	0.001863933	0.986486486	0.000607852	1.001921195	-0.01543471
26	22	3	0.00139795	0.987884436	0.001498237	1.003419432	-0.015535
27	27	3	0.00139795	0.989282386	0.001006409	1.004425841	-0.01514346
28	21	2	0.000931966	0.990214352	0.001639964	1.006065805	-0.01585145
29	23	2	0.000931966	0.991146319	0.00137427	1.007440076	-0.01629376
30	26	2	0.000931966	0.992078285	0.001082978	1.008523054	-0.01644477
31	29	2	0.000931966	0.993010252	0.000875945	1.009398999	-0.01638875
32	34	2	0.000931966	0.993942218	0.000643069	1.010042068	-0.01609985
33	37	2	0.000931966	0.994874185	0.000545642	1.01058771	-0.01571353
34	45	2	0.000931966	0.995806151	0.000373025	1.010960735	-0.01515458
35	32	1	0.000465983	0.996272134	0.000723457	1.011684192	-0.01541206
36	38	1	0.000465983	0.996738117	0.00051809	1.012202282	-0.01546416
37	43	1	0.000465983	0.997204101	0.000407473	1.012609755	-0.01540565
38	49	1	0.000465983	0.997670084	0.000316141	1.012925896	-0.01525581
39	50	1	0.000465983	0.998136067	0.000303972	1.013229868	-0.0150938
40	51	1	0.000465983	0.99860205	0.000292499	1.013522367	-0.01492032
41	52	1	0.000465983	0.999068034	0.000281669	1.013804037	-0.014736
42	65	1	0.000465983	0.999534017	0.000182579	1.013986615	-0.0144526
43	68	1	0.000465983	**1**	0.000167254	1.01415387	**-0.01415387**
		2146	**1**				

Figure 1 graphically represents the author's productivity, and the map plotted along with the number of inputs on the "X" axis and the percentage of the author on the "Y" axis. An extended tail distribution denotes very few events of more frequency, and many occurrences of less frequency, hence graph shows a "long tail" which is generated by an inverse square law relationship, meaning there is an inverse relationship between the numbers of papers published and authors contribution.

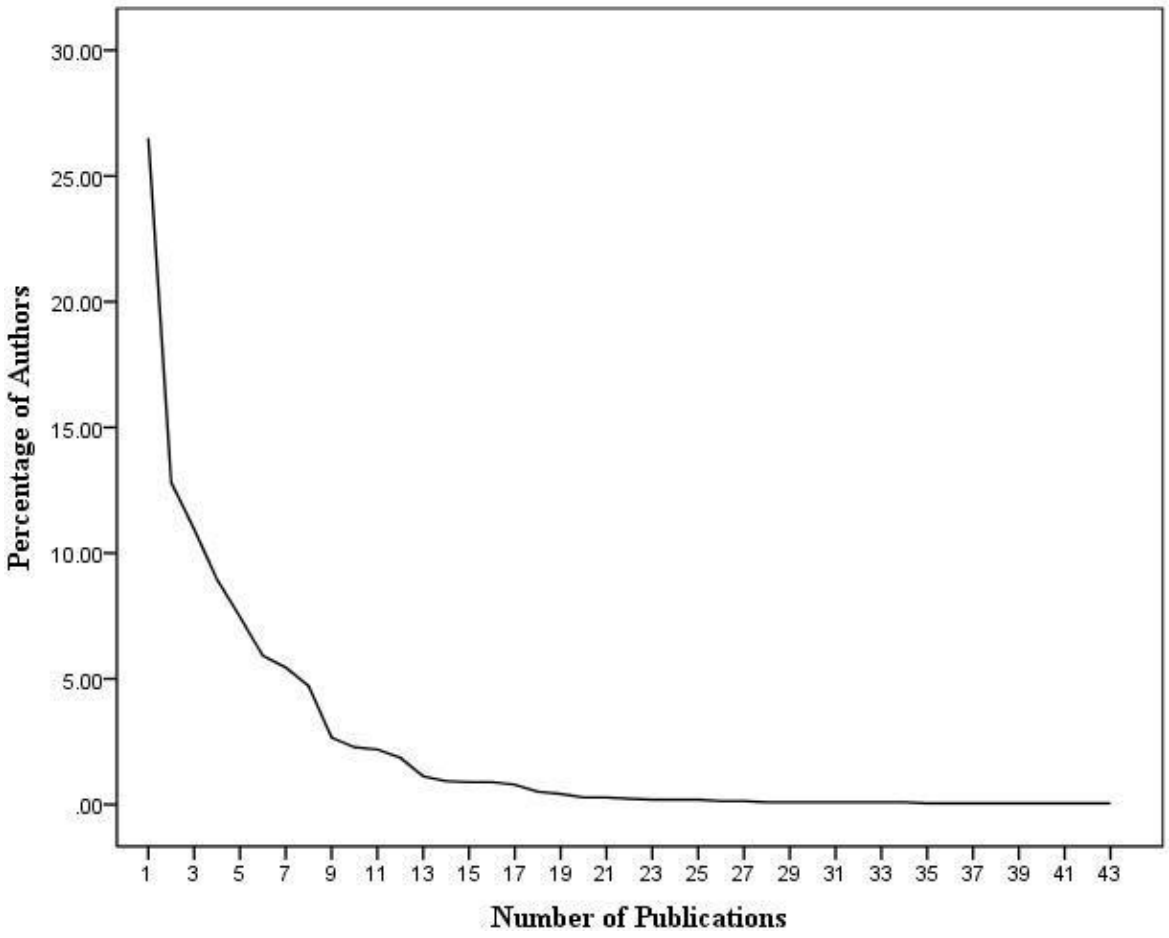

Figure 1: Author Productivity Fit for Lotkas Law

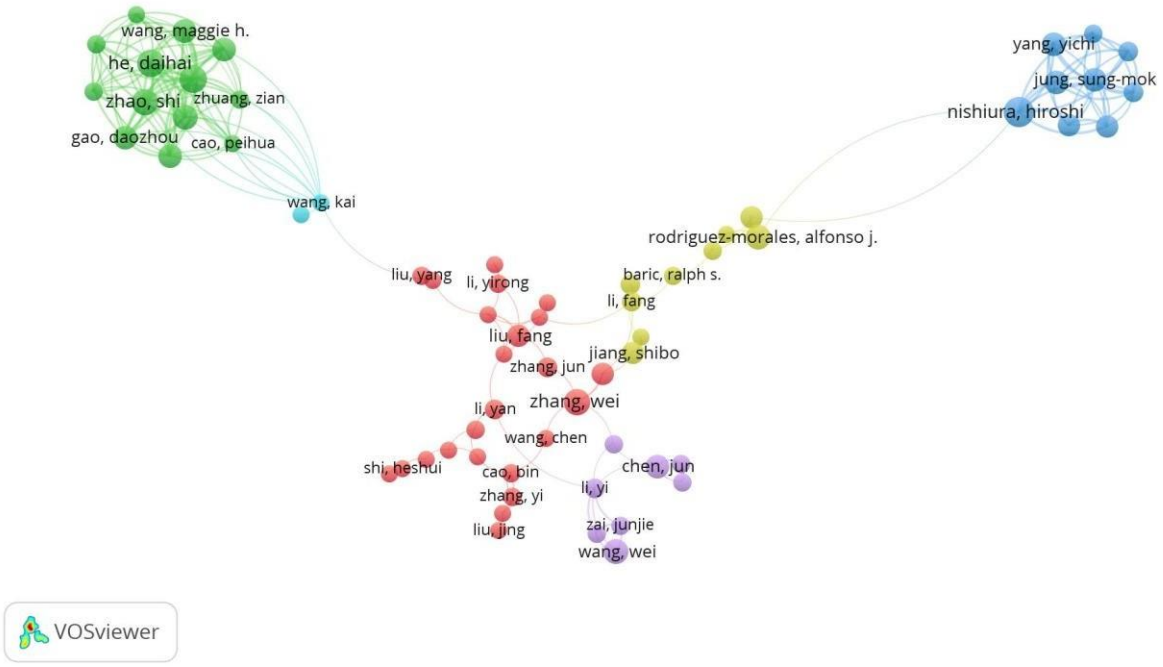

Figure 2: Co-Authorship pattern of COVID-19 research

Taking a minimum of 5 authors per document, of the 7735 authors 118 met the threshold. For each of 118 authors, the total strength of co-authorship links calculated, the authors with total link strength selected. Co-authorship pattern of COVID-19 research shown in figure2. A total of 6 clusters with 65 authors formed, "Nishiura, Hiroshi" (cluster 3- blue) tops the list of co-authors with ten links, 65 Total Link Strength(TLS), and 15 publications. At the same time "He, Daihai" (Cluster 2-green) contributed 13 documents (13 links, TLS-101) followed by "Zhao, Shi" (cluster 2-green) with 12 contributions (13 links, TLS-98) and "Zhang, Wei" (cluster 1-Red) with twelve publications(4links and TLS-7). Following authors have also contributed significantly to COVID-19 research:

- Wang, Wei (Cluster 5, purple), 10 documents, three links, TLS-10
- Rodriguez-Morales, Alfonso J (Cluster 4, Yellow), 10 papers, four links, TLS-11
- Gao, Daozhou (Cluster 2, green), nine articles,13 links, TLS-82
- Chen, Jun (Cluster 5, Purple), nine documents, four links TLS-8

- Jung, Sung-Mok (Cluster 3, Blue), nine documents, nine links TLS-57
- Yang, Yichi (Cluster 3, Blue), nine documents, eight links TLS-57
- Liu, Fang (Cluster 1, Red), eight documents, five links TLS- 6
- Giang, Shibo (Cluster 4, Yellow), eight documents, two links TLS-4
- Wang, Kai (Cluster 6, Cyan), five documents, 12 links TLS-21

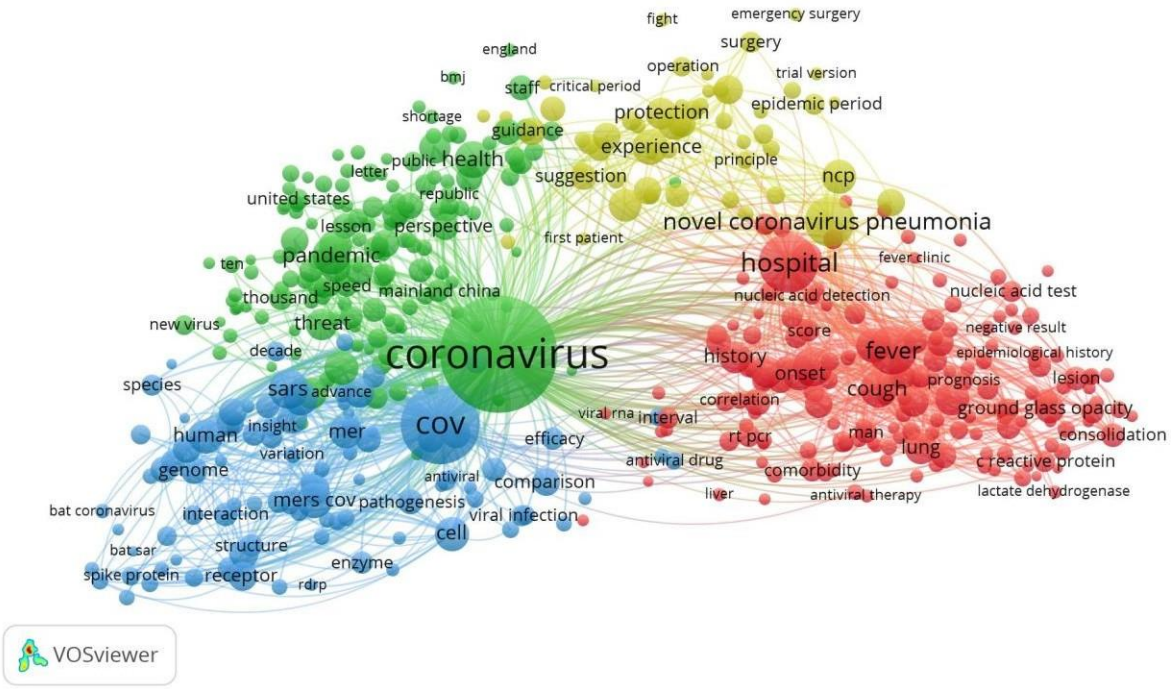

Figure 3: Title and Abstract of COVID-19 Viruses

With a minimum occurrence of 10 words in Title /Abstract related to COVID-19 research, of the 20674 terms, 797 met the threshold. For every 797 terms, a relevance score calculated. Based on the score 478 most relevant terms were selected. As shown in Figure 3 four clusters formed.

- Cluster 1 (Red) was related to the term "hospital" with 418 links, TLS-3,177and 247 occurrences. The terms "fever, lung, C-reactive protein, nucleic acid test, rtPCR, co-morbidity" were found closely associated with the cluster.
- Cluster 2 (Green) was associated with the term "Coronavirus" with 477 links, TLS-8,162 and 957

occurrences. The terms "health, pandemic, threat, United States, France, London, researcher were found relevant to the cluster.

- Cluster 3 (Blue) connected to the term "CoV" with 460 links, TLS-4,337 and 435 occurrences. The terms "sars, mers, cov, receptor, human, cell receptor, spike protein" were related to the cluster.
- Cluster 4 (Yellow) was linked to the term "novel coronavirus pneumonia" with 330 links, TLS-1,850 and 181 occurrences. The terms "coronavirus, CoV, hospital, emergency surgery, medical staff, ncp, guidelines, fight" were found closely associated with the cluster.

Conclusion

The Lotka's Law of author productivity viewed as one among the classic laws of bibliometric. The current examination demonstrated that Lotka's inverse square law supports author productivity on COVID-19 research. K-S test found to help the relevance of Lotka's Law of author efficiency. Further, the most significant authors and the most applicable terms found in the title/theoretical of distributions are the plots. This preliminary study on authorship productivity in the field of COVID-19 research may help to trigger intense research in the years ahead. Future research could direct authorship and productivity studies based on various institutions in the country and contributions from different databases.

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